TECHNICAL GUIDANCE DOCUMENT

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Effects of Organic Shale on TPH

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New Albany Shale Occurrence and Characteristics

The New Albany Shale is divisible into three parts. The upper New Albany is Mississippian in age; the middle New Albany is Upper Devonian, and the lower New Albany is Middle Devonian. The New Albany Shale as a formation generally varies in thickness from 100 to 340 feet. Parts of the New Albany are brown to black shales that are rich in organic materials. On weathered surfaces, the color is gray.

The New Albany Shale occurs across a wide area of Indiana (Figure 1). The outcrop/subcrop area of the New Albany shale extends from near New Albany (hence the name) in Floyd County near the Ohio River, north-northwestward though central Indiana and Indianapolis, and onward to Newton County along the Indiana-Illinois border. This outcrop/subcrop area exists on the southwest flank of the Cincinnati-Kankakee Arch, which separates the Illinois and Michigan Basins. In the northern tier counties of Indiana, on the south flank of the Michigan Basin, the Antrim shale, which is the stratigraphic and age equivalent to the New Albany, exists at depth. Here, the shale may be overlain by hundreds of feet of glacial material.

The amount of organic carbon in the New Albany Shale is quite variable, both stratigraphically and areally, ranging from less than 0. 1 to more than 20 weight percent (Frost and Shafer, 2000). Organic carbon content as high as 25 percent has been reported in a few thin organic-rich beds in Clark County, Indiana (Leininger, 1981).

Shale samples from cores of the New Albany and Antrim Shales, representing a broad geographic area of Indiana, have been analyzed for total organic carbon, total sulfur, pyrolysis yield (Rock-Eval), bitumen content, and illite crystallinity data (Guthrie 1989). These data indicate that the New Albany and Antrim shales contain a sufficient quantity and quality of organic matter to be good petroleum source rocks. It is reported that the New Albany Shale generally contains from 10 to 15 gallons of oil per ton (Campbell and Wickwire 1955, and Matthews et al 1980). The New Albany is both a source of petroleum to surrounding rocks as well as a direct producer of hydrocarbons. Recently, the New Albany and Antrim black shales have been drilled for the recovery of natural gas.

Abundant black organic-rich shales also occur in rocks of Pennsylvanian age in southwestern Indiana. They have not been well characterized except for a few thin intervals in small areas, the best example being at the abandoned Mecca Quarry (Parke County) in west-central Indiana. Although these shales are thinner and less widespread than the organic-rich shales of the New Albany Shale (Devonian age) they warrant characterization because of their accessibility during strip mining of underlying coals. Organic-rich shales of Pennsylvanian age contain up to 44% organic carbon and might be considered potential oil shales. Carbon to hydrogen ratios in these shales are similar to those in the New Albany. Relatively high concentrations of certain metals occur in shales of both ages, especially where phosphate is abundant, and sulfur values for both shales range from < 1 to 6%. Sulfur values are much higher for thin pyrite-rich units.

Relevant Glacial Processes Affecting Clay and Black Shale Distribution In Tills

Evidence from a few isolated areas of thick deposits indicates that at least 11 different and distinct glacial events affected the state. The events and the glacial deposits of the Ice Age are divided into three great stages, the most recent is the Wisconsin Stage, which began about 50,000 years ago. Nearly all of the modern landscape of the northern two-thirds of the state, and a large part of the deposits beneath, are the product of this stage.

Three major late Wisconsin glacial episodes are recognized in Indiana (Figure 2), beginning with the advance of the Huron-Erie Lobe from the northeast about 22,000 years ago (Fleming and Rupp, 2008). This event produced the most widespread sequence of glacial deposits, known as the Trafalgar Formation, which is found throughout the subsurface in Indiana and extends well south of Indianapolis and westward into eastern Illinois. This sequence is dominated by abundant fragments of bedrock units that crop out east of Indiana – Ordovician limestone from the Lake Ontario basin, and Silurian dolomite, Devonian limestone, and Devonian black shale from Ohio—indicating the direction of ice flow from east to west. A second sequence, known as the Huntertown Formation and found only in the subsurface of northern Indiana, contains characteristic fragments of sandstone, coal, and red mudstone from the Michigan Basin, as well as distinctive metamorphic rocks from the north shore of Lake Huron, suggesting that the ice that deposited it came directly from the north. This ice sheet is called the Saginaw Lobe. The late Wisconsin culminated in the re-advance of the Erie Lobe into northeastern Indiana, which produced the third major sequence of deposits. Known as the Lagro Formation, this last sequence immediately underlies and is responsible for the form of the modern land surface throughout most of northeast Indiana and is characterized by its extremely clay-rich composition, reflecting the fact that the ice sheet advanced across the bed of a vast glacial lake containing clays (the forerunner of Lake Erie) as it approached Indiana.

It is thought that the glaciers that affected Indiana probably moved relatively rapidly because they had abundant water at their bases to help "lubricate" their sliding motion over their beds. This sliding motion allows a vast amount of older rock and sediment to be eroded from the bed of the glacier, where it becomes frozen into the lower part of the ice. Thus, glaciers could be viewed in one sense as "conveyor belts", constantly transporting sediment from back up under the ice to the glacier margin. The edge of a glacier is where the ice is always melting. When melting rates are slow (for example, during winter or other especially cold times) and accumulation of new ice is rapid, the ice margin moves outward, or advances, whereas when melting rates are high, the opposite is true. In any event, the constant melting that goes on at the margin of a glacier releases vast amounts of entrained sediment, some of which may have traveled as frozen debris in the glacier for hundreds or even thousands of miles from its source. At the scale of the continental ice sheets, the quantity of sediment transported must have been astonishing. In Indiana alone, countless tens of feet of soil and bedrock were stripped off the landscape and redeposited down-glacier, along with even larger quantities derived from areas farther north. The glacial episodes altered all aspects of the area's hydrology and hydrogeology. Because each successive advance and retreat of glacial ice caused erosion and redeposition of earth materials, glacial sediments and their hydrogeologic properties are very complex.

As regards distances of transport, results are mixed. Klassen (1995) has documented transport of resistant clasts from beneath the Keewatin ice divide over distances of tens to hundreds of kilometers. Anderson (1957) found that pebbles in Erie-lobe till in Indiana were comprised of 36% Ordovician limestone, presumably from eastern Lake Ontario 600-700 km away, and 24% Precambrian clasts from even farther away. Harrison (1960) argued that nine tenths of a till, also in Indiana, was derived from distant sources, and that the till reflected equal erosion rates per unit bed area throughout the length of a flow path originating in Labrador. On a smaller scale, Clark and Karrow (1983) showed that pebble lithology in till in northern New York changes rapidly across bedrock lithological boundaries, and is mainly a function of whatever bedrock the till overlies. Hicock (1986) found that clast dispersal distances were short (20 km or less) in an alpine setting on Vancouver Island. Hicock and Kristjansson (1989) found similarly short dispersal distances in northern Ontario. Holmes (1952) found that over 95% of pebbles in till in west-central New York had travelled less than 80 km (50 miles). He documented the disappearance of pebbles of black shale within 6.5 km (4 miles), in contrast to the survival of resistant sandstone clasts over tens of kilometers.

Most deposition associated with glaciers takes place at or near the ice margin. The particular type of deposit and its expression as a landform depend on the dynamics of the glacier, the mechanics of sediment transport within the glacier, and the method of sediment deposition (Schrader and others 2002). Through time, accumulation of ice toward the center of a glacier is balanced by melting at and near the margin. This equilibrium has two important consequences. First, the outward flow of ice within the glacier transports sediment to the ice margin where it is deposited by a variety of processes. Second, the melting ice front feeds meltwater streams that flow both away from and parallel to the ice margin. The high energy typical of most meltwater streams results in the removal of silt and clay from the glacial debris. This process commonly concentrates sand and gravel in the form of outwash deposits.

Within a depositional system, the relative coarseness of the outwash sediments tends to decrease with increasing distance from the ice front. Outwash bodies range from narrow and discontinuous channels to broad, regionally extensive plains and fans. The detailed geometry of outwash bodies depends on such factors as the configuration of the landscape over which the meltwater flows, the size and location of meltwater outlets from the ice front, the sediment load each meltwater stream carries, and the behavior and duration of the ice front at a particular location.

Outwash constitutes several landforms within central Indiana. It forms valley trains along the White River, Fall Creek, Eagle Creek, Mud Creek, other tributaries, and numerous high-level channels, as well as broader fans like the one referred to by Fleming et al (1995) as the Glenns Valley fan in the vicinity of Greenwood. Some of the outwash deposits that occur in central Marion and Johnson Counties are medium-grained, poorly-sorted sediment that was transported near the base of the glacier and deposited directly by ice with minimal reworking by meltwater and mass movement. Most till contains scattered rock fragments set in an overconsolidated fine-grained matrix. Each ice advance tends to produce a characteristic till sheet that can usually be distinguished from other till sheets on the basis of grain-size distribution, combinations of rock and mineral fragments unique to a particular source area, and other diagnostic attributes. The relative proportions of sand, silt, and clay that form the matrix of any particular till unit depend on the source area of the glacier as well as on the kinds of processes that release the sediment from the ice.

Numerous factors such as glacier dynamics, topography of the underlying bedrock, Bedrock lithology, amount of bedrock exposure, and dilution by older glacial deposits affect the texture and composition of tills. Within a given unaltered glacial till unit, there is a remarkable lack of variation and may represent some process of homogenization of fine particles during glacial transport. Changes in clay mineralogy generally reflect a regional change in the underlying bedrock. Older Paleozoic shales (Cambrian through Mississippian in age) within the glacial till plains contain more illite and chlorite than kaolinite, whereas Pennsylvanian shales or underclays of the plateau (a more eastern source) contain a larger proportion of kaolinite (Volpi and Szabo 1988). Another factor, as yet unquantified, is the effect of the incorporation of weathered older glacial deposits into younger tills. Weathered tills should contain kaolinite and expandable clay minerals.

COMMENTS AND EVALUATION

Recently, there has been literature and environmental consultant support of the potential presence of low-level concentrations of naturally-occurring petroleum hydrocarbons often detected within certain glacial deposits during subsurface investigations at environmental sites. The New Albany and Antrim black shales of Indiana are known to have a high organic content and have been well-studied as petroleum source rocks as well as direct producers of hydrocarbons. In areas where they are at or near the surface, the New Albany and Antrim shales have been subject to extensive surface weathering prior to and between each glacial advance and have been eroded and continually reworked by glacial processes.

Geologic setting and environment of deposition can be used to characterize and predict the likely presence or preservation of black shales in glacial till soils, and narrow the geographical areas where differentiation of naturally-occurring constituents from historical petroleum releases is needed.

The clay (shale) portion included in the matrix of any particular till unit depends on the source area of the glaciers as well as on the kinds of processes that release the sediment from the ice. The clay content in the glacial tills of central Indiana comes from multiple source areas. Mundell (2002) theorized that either the New Albany Shale from the Marion County area or Antrim Shale from northern Indiana were the specific units from which any shale contained within the glacial till soils (at the Pogues Run site in east Indianapolis) was derived.

The New Albany Shale occurs in a narrow band extending through central Indiana (see Figure 1) either in outcrop directly at the surface or in subcrop as the upper-most bedrock unit underlying glacial and more recent sediments. The northern half of the New Albany subcrop area (roughly from Boone to Newton Counties) was subject to multiple glacial ice episodes (glacial lobes illustrated in Figure 2) which advanced from the northeast and north directions. This portion of the New Albany subcrop area was overridden by ice sheet advances and is now buried beneath tens to hundreds of feet of glacial material.

In northern Indiana, the New Albany Shale may have been directly encountered and picked up by the initial glacial ice sheets, but with each subsequent ice advance any shale clasts from the New Albany would have been subject to extensive reworking, erosion and weathering during transport from north-northeast to south-southwest. With transport and each subsequently advancing ice sheet the shale would be intermixed with glacial material of a different origin. Glacial till – defined as the unsorted sediment deposited directly from glacier ice with little or no reworking by meltwater or mass movement – predominates in the northern half of Indiana. The glacial tills of this region, would in effect, be diluted with respect to New Albany shale. With this alteration, the New Albany shale material would be subject to loss of volatiles and adsorbed hydrocarbon. To a minute degree, clay (shale) content attributable to New Albany may be preserved in the matrix of the deposited glacial tills, but the accompanying hydrocarbon would be subject to even greater loss. With this said, the environmental sites with historical petroleum releases in this area would not likely require differentiation from naturally-occurring hydrocarbons.

In the portion of the New Albany subcrop located near the glacial ice margin (roughly Boone County south to Bartholomew County), extensive melting of the glacial ice and most of the deposition of entrained sediments took place. The high-energy meltwater streams flowing away from and along the ice margin resulted in the removal of silt and clay from the glacial debris. In general, with glacial processes, the softer rock varieties (such as shale) are worn down more readily than the hard resistant rock varieties. If shale clasts containing TPH are preserved in the glacial soils, they are locally derived, and are transported only a short distance prior to deposition. Likewise, TPH contained within the glacial soil matrix also appears to be locally derived from the New Albany subcrop area of central Indiana and is preserved due to less extensive reworking by glacial processes.

The Antrim Shale, also speculated to be a source of naturally occurring hydrocarbons, lies beneath the northern tier counties of Indiana (not shown on Figure 1 but extends from Lake County on the west to Dekalb County on the east). It may also have been directly encountered and picked up by the early glacial ice sheets, but with subsequent ice movement any shale clasts from the Antrim would have been subject to extensive reworking (or pulverization as Mundell (2002) suggests) as transport from northern to central Indiana took place. The Antrim Shale may be contributory to the fine-grained clay-size fraction of the glacial till matrix in central Indiana, but it highly doubtful that the petroleum hydrocarbons originally within this black shale would be preserved to any extent after the extensive reworking and transport by glacial processes.

After a literature review of glacial processes affecting Indiana, and the conditions needed for preservation of shale fragments within glacial till soils, it stands to reason that any naturally-occurring petroleum hydrocarbons derived from the New Albany Shale would be transported (and preserved) only a short distance (a few miles at most). Such occurrences are mostly likely to be located in central Indiana along the New Albany subcrop.

The fact that the New Albany Shale is high in organic content and bitumen/oil is well studied and is not disputed. Mundell (2002) offers supporting data through the review of chromatogram shape and relative peak characteristics and concludes that the TPH detected in undisturbed native soils at the Pogues Run site is derived from the naturally-occurring shale within the glacial soil matrix. Mundell identifies an elevated bedrock knob comprised of New Albany Shale within 1 mile of the Pogues Run site and theorizes that the shale in the glacial till soils is locally derived.

Mundell also discusses the re-analysis of Harrison (1959) data completed to determine the average percent of shale within glacial till samples from Indiana, and that a mineralogical analysis indicated a significant portion of the fine silt and clay size fraction of the tills contains the clay mineral illite. Mundell theorizes that the illite mineral "represents a contribution from a pulverized shale parent rock." Though not specifically stated, the paper implies that if the shale and illite clay are present then naturally-occurring TPH is present and preserved in the glacial tills. Weathering, physical breakdown, and dispersion of the shale, and the resulting loss of TPH from the shale, are not considered. Caution is advised when considering the TPH concentrations in New Albany and Antrim shale samples in Table 3 of the Mundell paper. The Antrim Shale samples exhibited TPH concentrations of 540 mg/kg and 1,100 mg/kg. The Antrim samples were collected from bedrock cores obtained from depths of 125 and 269 feet and have not been subject to near-surface weathering and alteration by glacial processes. Similarly, the analyzed New Albany shale sample (557 mg/kg) was collected from outcrop and was not subject to break-down by glacial processes. The outcrop sample and the shale clast samples picked from the glacial soil matrix (101 mg/kg to 790 mg/kg) are indicative of TPH values obtained through biased, selective sampling.

The samples collected from the undisturbed (glacial till matrix) soils at the Pogues Run project site reportedly exhibited TPH concentrations from less than 20 mg/kg to 98 mg/kg, with an average near 46 mg/kg. The Pogues Run site included two identified fill areas which were potential source areas for COCs. The number, and the vertical and lateral locations of the collected samples are not identified. It is not known if proper and representative background concentrations were determined for each soil horizon or appropriate interval, consistent with source area investigative results.

It is conceivable that New Albany Shale, the Pennsylvanian age shales associated with coals in southwest Indiana (described earlier), or any organic-rich black shale accessible in outcrop or man-made exposure could be used as fill material. The presence of New Albany Shale fill material has been identified at petroleum release sites in southern Indiana. In such cases, fill materials must be identified and characterized separately from COC source areas.

CONCLUSIONS

1) The New Albany Shale is an organic-rich shale and contains residuals of petroleum hydrocarbons.
2) The New Albany and Antrim Shales of the northern half of Indiana were exposed at the land surface and were eroded and transported by the initial advancing glacial ice sheets. The New Albany and Antrim Shales now lie buried beneath considerable thickness of glacial sediments. In this portion of Indiana, residual petroleum attributable to the New Albany and Antrim Shales and requiring differentiation from historical petroleum releases would not be expected.
3) Based on the geologic setting, environment of deposition, and the consideration of the affects of glacial processes, the New Albany Shale is a potential source of naturally-occurring petroleum hydrocarbons, measurable by TPH analysis, along its subcrop area and near the glacial margin. This occurrence and preservation of the New Albany shale within the glacial till soils is most likely in central Indiana along the subcrop area, notably within Boone, Marion, Johnson, and Bartholomew Counties.
4) Preservation and dispersion of TPH attributable to the New Albany Shale, within both the shale clasts and the glacial till soil matrix, is due to localized transport and deposition over just a few miles in distance.
5) Due to weathering, erosion, and breakdown of the shales by glacial processes, TPH concentrations within samples from the till soil matrix would likely be well below 100 mg/kg. TPH concentrations generally in the tens of mg/kg are expected.
6) At all sites where naturally-occuring TPH is expected or identified to be contributing to COC concentrations exceeding applicable IDEM closure levels, representative background sampling and analysis must be performed. Background concentrations in soil must be determined relative to COC source area concentrations.
7) Organic-rich black shales (known to contain naturally-occurring TPH) may exist as fill material at historical petroleum release sites. Such fill materials should be identified and characterized separately from COC source areas.

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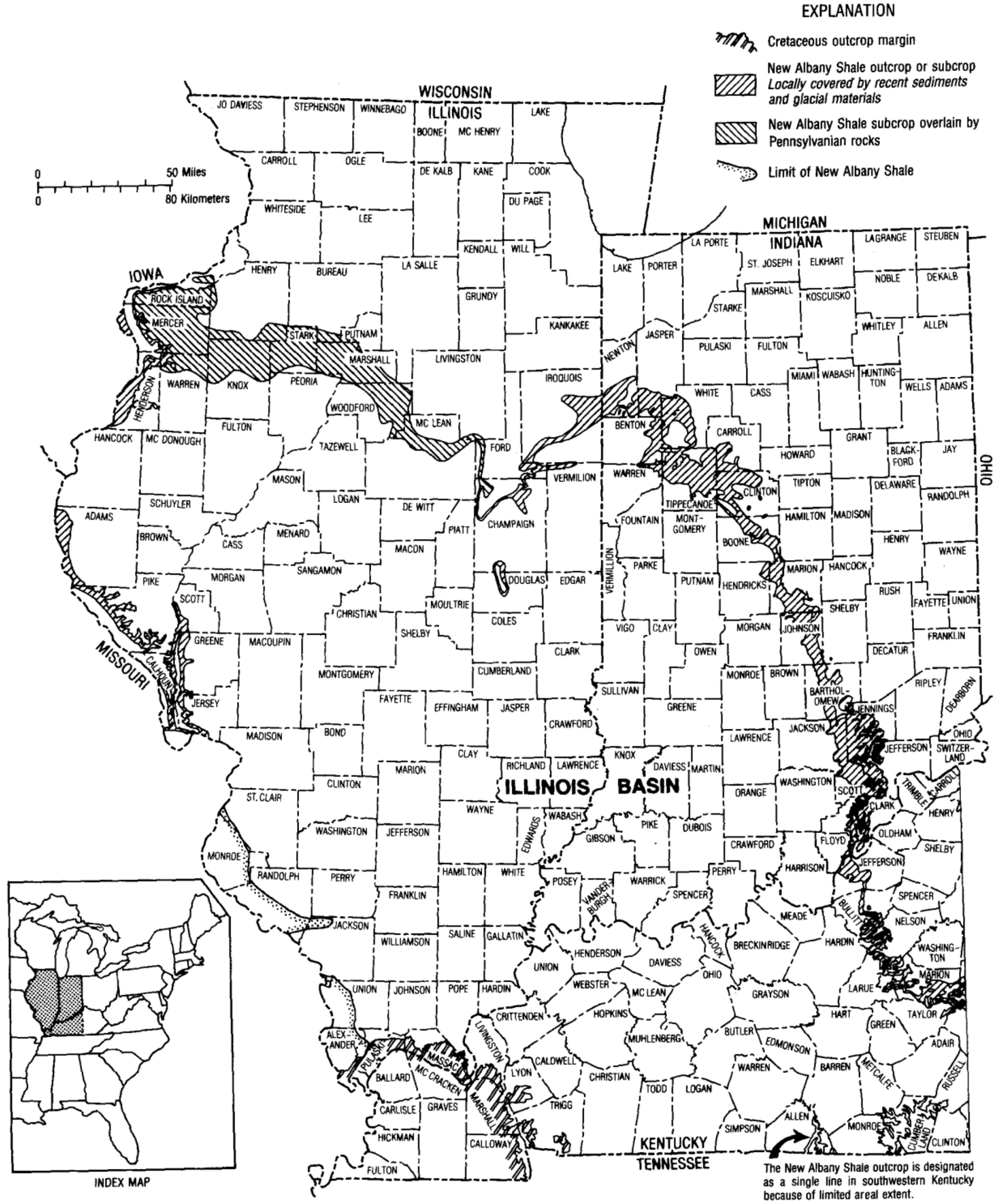

Figure 1. Map showing the location of the Illinois Basin, the outcrop of the New Albany Shale (Devonian and Mississippian), and county names in Illinois, Indiana, and Kentucky. The outcrop pattern defines the shape of the Illinois Basin. The New Albany Shale is present throughout the Illinois Basin. (From Gas Potential of the New Albany Shale, Hasenmueller and Comers, eds., 2000)

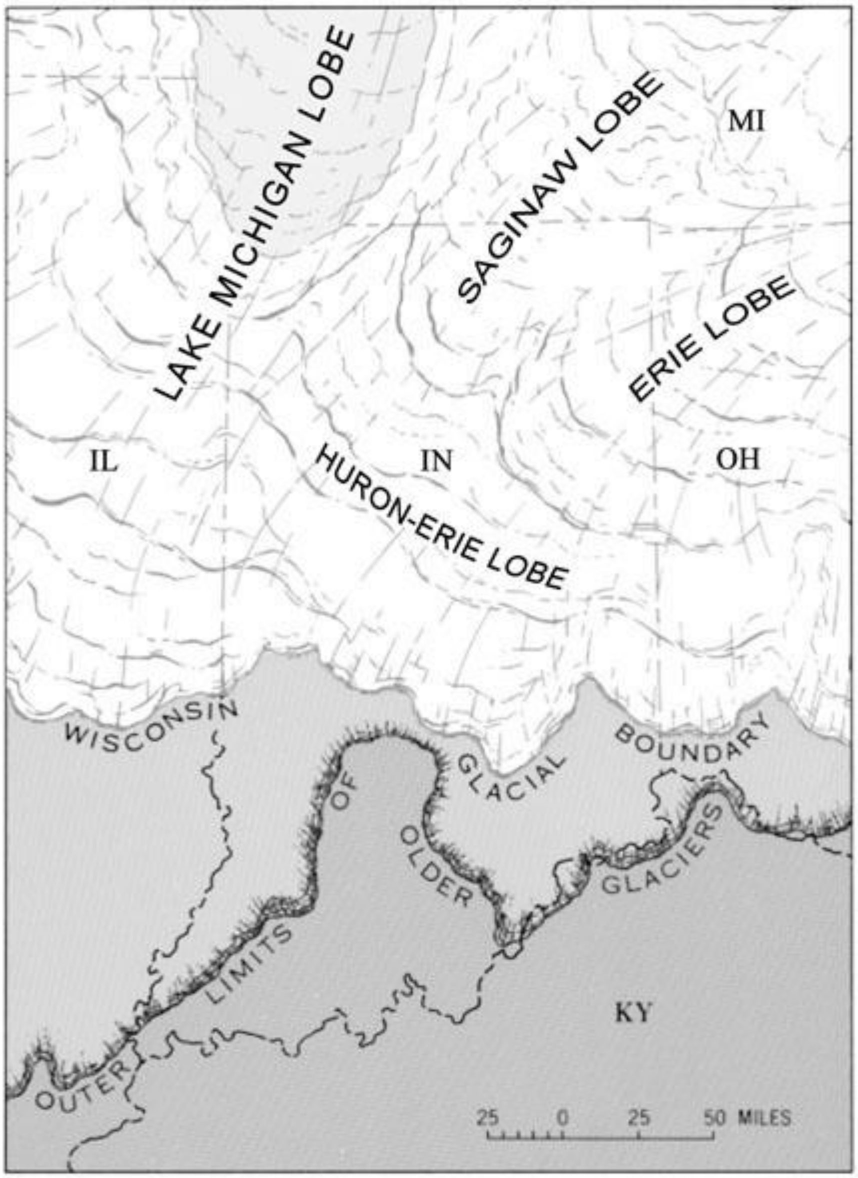

Figure 2. Map showing the most-recent glacial advances (lobes) affecting Indiana and the southern limits of Wisconsin age and older glacial areas of influence. (From Fleming and Rupp, In. Geol. Survey, 2008).